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Testing Overload Levels of Audio Amplifier using STELLA

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Abstract

Nowadays the output of typical car audio player is normally unlikely to generate sufficient power for audio speaker system, so power amplifier must be added to the circuit. The problem is that the technical descriptions and flowcharts usually do not show the crunch capacity and dynamic of amplifier devices. In order to not to blow the amplifier, it is crucial to know the allowed input power, timbre controls and power supply units preventing occurrence of possible power overload. Therefore four-channel (4X100W) power amplifier TK2050 has been selected for this testing purpose. The model of TK2050 electrical components was designed in ISEE Modeling & Simulation Software STELLA dynamically displaying the flow of power, as well as the occurrence of the overload levels depending on the change of input parameters. Following experimenting process led to awareness of input and output relationships in parallel and bridge circuits, element load changes depending on power supply usage, as well as interdependence of input power and EQ settings.

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1. Introduction

An amplifier is an electronic device that increases the power of a signal. With that being said, the purpose of every power amplifier is to take a relatively small signal from a source device (input device) and make it suitable for driving a loudspeaker (output device) by increasing its magnitude. For example microphone won't have enough strength to drive a loudspeaker directly, and no sound would be heard without using proper amplifier[1].

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Nowadays there are a lot of electrolytic components built-in to avoid overload occurrences. Many amplifiers have a number of features to help monitor the status of the amplifier and also to protect speakers (and the amplifier itself) in the case of an overload condition. Some features include power meters, clipping indicators, thermal overload shutdown, over current protection. Features vary from manufacturer to manufacturer. In addition, there are many variations in how protection circuits are implemented and how much "safety margin" they allow[2].

Although it is recognized that most of power amplifiers should never be subjected to overload, it is equally well recognized that it will happen at some stage[3].

Technical descriptions and flowcharts usually do not show the crunch capacity and dynamic of amplifier devices, so technically no user is fully protected from resulting overload by adjusting input and processing conditions that are not recommended by manufacturer. An overload can make a decent amount of clipping and distortion in output signal. Clipping can be very detrimental to speaker systems. Whenever clipping occurs, two things happen: the spectral content of the music signal is altered (high frequency components are generated), and signal compression occurs. If excessive clipping occurs, tweeters will be the first to blow followed by midrange drivers. Woofers are best equipped to survive clipping [2].

It's often stated that the cheaper the amplifier will be the lower quality user will get. The amplifier being tested in this research is considered to be in low-end price range. So testing process whether the cheaper ones can generate quality and sufficient input-output power ratio is needed.

2. Components and their functions

Before going further into modeling and testing processes, it is crucial to understand the basic elements and their functions of any basic amplifier:

- Chipset – integrated processing circuit in amplifier. Most chipsets are very effective and produce high quality sound, even though some consider chip-based amplifiers to be inferior to their discrete counterparts. The chips have been carefully designed to incorporate a number of desirable features, including excellent power supply rejection ratio, fast response, accurate bias current, over-temperature protection and short circuit protection[4];
- Capacitor - widely used in electronic circuits for blocking direct current while allowing alternating current to pass. In analog filter networks, they smooth the output of power supplies. In resonant circuits they tune radios to particular frequencies. In electric power transmission systems, they stabilize voltage and power flow[5];
- Fuse - type of low resistance resistor that acts as a sacrificial device to provide overcurrent protection, of either the load or source circuit. Its essential component is a metal wire or strip that melts when too much current flows through it, interrupting the circuit that it connects. Short circuits, overloading, mismatched loads, or device failure are the prime reasons for excessive current[6];
- Resistor - implements electrical resistance as a circuit element. Resistors act to reduce current flow, and, at the same time, act to lower voltage levels within circuits. In electronic circuits resistors are used to limit current flow, to adjust signal levels, bias active elements, terminate transmission lines among other uses[7];
- Induction coil - type of electrical transformer used to produce high-voltage pulses from a low-voltage direct current (DC) supply. To create the flux changes necessary to induce voltage in the secondary, the direct current in the primary is repeatedly interrupted by a vibrating mechanical contact called an interrupter[8].

Based on theoretical knowledge above, it is easy to understand, that amplifiers could be very different in many dimensions starting from complexity level of electrolytic elements' circuits till output power they generate. For this testing purpose one of the simplest ones is selected in order to be able to construct the model that is easy to understand, showing the basic electrolytic elements every amplifier has and testing them.

3. TK2050 audio amplifier

Based on TC2000 chips from Tripath, Class-T TK2050 audio amplifier simplifies the creation of custom multi-channel systems. Compatible with power supplies ranging from 5V DC to 30V DC (with recommend of 24V). It can be used in many audio applications. TK2050 is capable to handle 40W on audio input power (with recommend of

30W). The amplifier has four output channels with the power up to 100 watts each, resulting in outstanding sound quality and versatility. Customers can employ any number of channels they like, and leave the others unused by using bridge circuit connection[9]. TK2050 is well designed, with a lot of power reserve, high fidelity, low distortion, good S/N ratio, high sensitivity, and full protection with heat sink and fan. As it is said by developer: *"These ideal characteristics make this amplifier a candidate to become the basic building block of your future high fidelity system, or it can become the element that will upgrade an existing system"*[10]. According to technical descriptions, TK2050 amplifier also has over voltage protection, over current protection and over temperature protection[9]. As it was said earlier, technical descriptions and flow charts do show that overload elements exist, but, unfortunately, they do not show the overload levels they are capable to endure. In order to determine what input values customer can adjust to be able to use his TK2050 with high level of satisfaction, it needs to be tested.

3.1. Modelling

The model of TK2050 electrical components was designed in ISEE Modeling & Simulation Software STELLA. Modeling led to ability to dynamically display the flow of power, as well as the occurrence of the overload levels depending on the changes in input parameters (see Fig. 1).

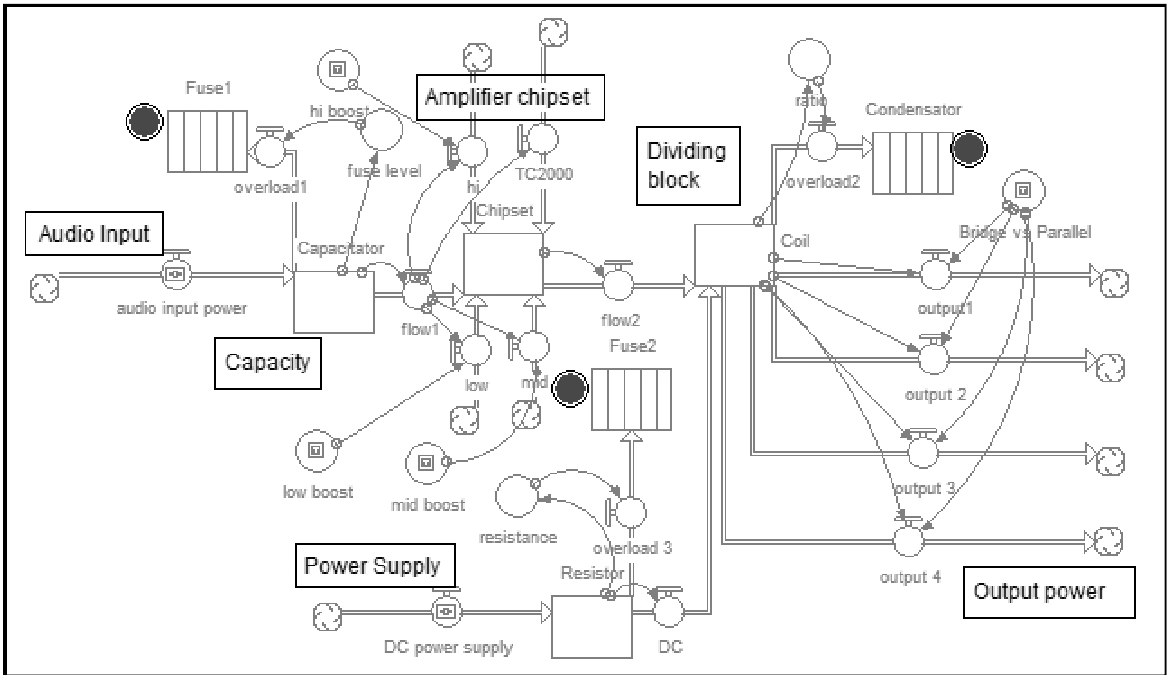

Fig. 1. TK2050 model in STELLA simulation software.

TK2050 STELLA model can be divided in six different function blocks: audio input, capacity, chipset, dividing, power supply and output blocks, where:

- Audio input block - receives an audio input signal from stereo/mono device connected to amplifier;
- Capacity block – blocks direct raw signal, allowing alternate signal to pass;
- Chipset block – processes an audio input by chip and EQ;
- Dividing block – splits the signal into four or two outputs based on what circuit connection is selected;
- Output – transmits audio signal to playback devices connected to amplifier;
- Power supply – DC input.

The model can be also divided by types of modelling elements that have been used to construct it. In order to build above mentioned blocks and connect them together, there are five different kinds of elements, where:

- Stocks (shown as rectangles in Fig. 1) - store audio signal or voltage during the simulation run;
- Flows (shown as faucets in Fig.1) – add or subtract amount of watts or volts in specific stock;
- Converters (shown as white circles in Fig. 1) – contain specific value or value table for equitation in stock or flow;
- Connectors (shown as arrows in Fig. 1) – indicate the reciprocal relations of modelling elements;
- Testing points (shown as black circles in Fig. 1) – do overload testing of capacitor and fuses. Points are using the following colour scheme: green - no overload condition is fixed, yellow – condition is close to overload level, red – overload condition is met.

3.2. Technical parameters

As in every dynamic modelling scheme, there are values, equations and formulas hidden under each of the elements, in order to run it properly. This section will reveal the basic algorithms making the flow of watts and volts respectively.

Audio input block - audio input is being selected manually, allowing user to change it depending on desired condition. User has an option to adapt an audio input starting from 10W to 60W while recommended value is 30W (as being set by basic value).

Capacity block – if capacitor meets overwhelming input power, then current overload level is sent to fuse. To detect this condition, fuse level meter adapter is used in modelling scheme (see Fig. 1).

Chipset block - the main functional block of amplifier, where the audio signal is being processed. Processing algorithms are being determined by TC2000 chipset and EQ scheme (see Fig. 1).

Dividing block – accumulates input power and prepares to divide it. The basic element is coil, where overload ratio meter is used to prevent coil from heating up (see Fig. 1).

Output - generated by the algorithm included in user interface. If the bridge connection is selected, the bridge/parallel converter switches TK2050 to 1st and 4th output channel mode. If parallel connection is selected all four channels are active.

Power supply – DC input is adapted by user. While 24V is recommended by manufacturer, user has an option to change it in the interval starting from 5 to 30V.

Basic values of input elements – audio input, DC input and EQ were set as recommended by manufacturer in user manual[9].

To validate the technical data, given inputs should be equal to fixed output values. In case of this amplifier, 40W audio input to 24V power supply should generate 100W on each output. Model did exactly the same values as they were predicted in user manual.

In order to make technical data a bit more user-friendly, a simple visualization tool was created for displaying the values of input and output data (see Fig. 2).

Fig. 2. Audio input and output visualization tool.

First one from the left stands for audio input level, and the others to the right are output audio meters. They do use the same technique as overload testing points described earlier. Green - no overload condition is fixed, yellow – condition is close to overload level, red – overload condition is met.

3.3. User interface

In order to facilitate the chance to experiment with model, user interface has been created. User interface is based on three types of controls: bridge and parallel switch, timbre and EQ controls and input power (Audio/DC) options.

Bridge and parallel switch gives an option to turn on or turn off one of the mentioned circuits by going into other. If the switch is up - the amplifier runs in bridge mode, if it's down – parallel connection is active.

Timbre/EQ controls are handy for user if there is need to make some adaptions in frequencies spectrum of input audio signal. User has an option to switch between low, mid and hi frequencies spectrum boosts. By the desire of user, there is also an option to switch on several frequencies at the same time. When the switch is up, the boost is on, when it's down – the boost is off.

Input power options are used for adapting audio and DC input levels. User has an option to set the values manually by clicking in the value boxes and typing them manually or to set them by using the slider tool above the value box. Audio input level can be adjusted in range from 10 to 60 watts. DC power supply can be adjusted starting from 5 to 30 volts.

4. Methodology

The methodology chosen for this project is multi-set experiments with input parameters of TK2050. Model had been run in total of 7 sets adjusting different conditions of parameters. Each set was run X times till the desired output condition (overload) in particular elements (fuses and output) was met. Running sets, their conditions and testing purposes are defined below:

- 1st set of runs. Conditions: all parameters on basic (audio input = 30W, low boost = off, mid boost = off, hi boost = off, DC = 24V). Testing overload and audio output values on different circuit modes by switching between parallel and bridge connections;
- 2nd set of runs. Conditions: low boost = off, mid boost = off, hi boost = off, DC = 24V. Testing overload and audio output values to reach max (100W on each output) by increasing audio input value;
- 3rd set of runs. Conditions: audio input = 30W, DC = 24V. Testing overload and audio output values by enabling EQ boosts one by one (low + mid + hi). When all EQs enabled, increasing audio input to max = 40W;
- 4th set of runs. Conditions: audio input = 30W, low boost = off, mid boost = off, hi boost = off. Testing overload and audio output values by increasing DC values. When DC max = 30V, increasing audio input to max = 40W;
- 5th set of runs. Conditions: audio input 30W, low boost = off, mid boost = off, hi boost = off, DC = 24V. Testing overload and audio output values by increasing audio input and DC input values proportionally by 1W and 0,6V respectively. Each run must be repeated by all EQs on and off;
- 6th set of runs. Conditions: audio input 30W, low boost = off, mid boost = off, hi boost = off, DC = 24V. Testing overload and audio output values by increasing audio input to max (40W) and decreasing DC to min (5V);
- 7th set of runs. Conditions: audio input 30W, low boost = off, mid boost = off, hi boost = off, DC = 24V. Testing overload and audio output values by increasing DC to max (30V) and decreasing audio input to min (10W).

5. Results

Working on recommend conditions, overload levels are not fixed neither in fuses or audio output levels. TK2050 can generate 76,5W on parallel and 153W on bridge connections.

Maximal audio input power, remaining other parameters as recommended, is 40W. Working on maximal input conditions TK2050 output power can reach up to 100W per channel in parallel connection.

If any of EQ boost functions are enabled while TK2050 is receiving maximal audio input conditions and being powered by DC 24V, overload condition is met.

Increasing input audio above max (40W) led to overload in output levels. Overload condition in capacitor was met while running on 48W audio input power.

DC 24V input is definitely recommended to run TK2050. Input voltage increasing from 24V to 30V didn't affect audio output levels noteworthy instead of causing overload in power supply block.

TK2050 works efficient even if the DC input power is under recommended, although it wasn't able to reach as high input levels as they were while working on recommended conditions.

6. Conclusion

To sum up, studies have clearly shown that even low-end amplifier can generate sufficient power for mid-range speakers, so this would be a worth product for customer aiming to satisfy their needs on low budget. Cause of ability to switch between different circuit connections, current amplifier can generate output signals up to five times stronger compared to input value.

Multi-experimenting process led to awareness of TK2050 overload durability depending on adjustment of input parameters. Amplifier and its electrolytic components can withstand working conditions up to 48W audio input and 30V DC power supply, which could be evaluated as a high overload durability compared to recommendations 30W and 24V respectively.

When it comes to amplifiers and their flowcharts, topic about dynamic system modelling will be important in future as well. Some ideas for next researches would include testing the amplifier and its durability in previously defined time periods and by modelling heating temperatures of particular elements of amplifier. Another dimension would be to study the quality of output power based on overload appearances described above. To be even more innovative, it would be useful to simulate the electrolytic schemes of some higher-class amplifiers and later compare them by their performance and durability against overload conditions.

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